South Carolina Blue Ridge, Ecoregion 66
Stream Morphology and LWD Results

In the South Carolina Blue Ridge, Ecoregion 66, six streams were visited in April, 2019, to collect geomorphic data for comparison to hydraulic geometry regional curves available for the North Carolina Blue Ridge Ecoregion (Figure 1 and Table 1). Site 1 is an active USGS gage on the Middle Saluda River with a watershed drainage area of 20.8 square miles. The other five sites are reference streams in forested watersheds with drainage areas ranging from 0.11 to 2.01 square miles.

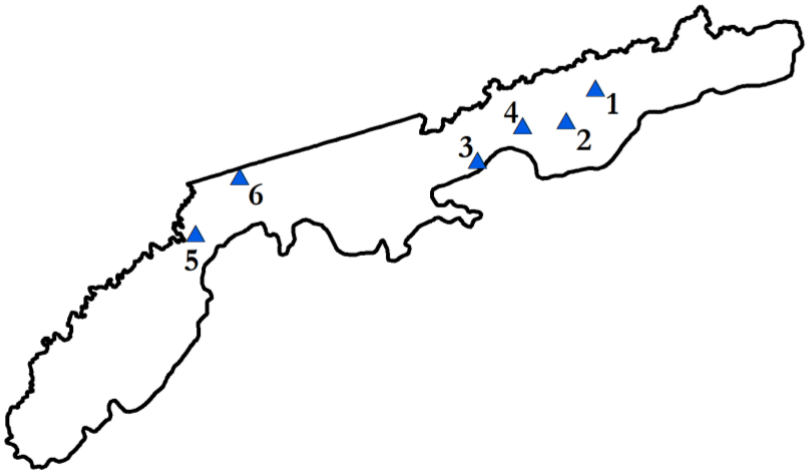

Figure 1. Reference Stream Sites in Ecoregion 66, South Carolina.

Table 1. Reference Stream Sites.

Site	Stream name	Source/Location	Latitude	Longitude	Drainage area (mile^2)
1	Middle Saluda River	USGS gage	35.120115	-82.537465	20.8
2	Wattacoo Creek	Naturaland Trust	35.081739	-82.578104	2.01
3	Green Creek	Table Rock State Park	35.034476	-82.701337	0.35
4	UT Matthews Creek	Asbury Hills Camp	35.075628	-82.638887	0.11
5	Crane Creek	Sumter National Forest	34.943975	-83.095603	0.27
6	Howard Creek	Sumter National Forest	35.010530	-83.034919	0.56

The Middle Saluda River USGS gage station was included in this study because the long-term records for flow stage and discharge can be used to quantify the specific channel-forming discharge exceedance probability for bankfull conditions. Discharge can be reported in terms of exceedance probability (or return period) to assist in determining channel-forming discharges and morphological indicators in ungaged watersheds. The Middle Saluda gage site is at a stable stream location in a relatively undisturbed watershed with field indicators of bankfull stage near a riffle downstream of the gage.

The reference streams in this Ecoregion were selected in consultation with SCDNR and other local stream professionals to identify reference reaches based on the following criteria:

- Watersheds with drainage areas ranging between 0.1 and 10 square miles;
- Watersheds with stable land use, mostly forested, over the past several decades;
- Stream channels and floodplains in equilibrium with active bankfull stage indicators (bank height ratios near 1.0);
- Stream channels with freely-formed meander patterns in low-gradient valleys and natural step-pool bedforms in high-gradient valleys; and
- No valley restrictions throughout the reference reach or upstream/downstream that may influence channel form;
- Healthy riparian forest buffers;
- Accessible for data collection and protected for future access.

For each stream site, field data on stream geomorphological characteristics were collected to establish hydraulic geometry relationships, in addition to collecting large woody debris (LWD) information[1]. The geomorphological characteristics were collected following the methods outlined in the most revised version of the North Carolina SQT Field User Manual[2] and the LWD assessment was in accordance with the most revised version of the Application of the Large Woody Debris Index Field User Manual developed by Stream Mechanics and Ecosystem Planning & Restoration. All reference stream assessments included collection of dimension (cross-sectional) data. As conditions allowed, pattern and profile data were collected for a subset of the reference sites.

Field data collected (in addition to LWD) at all reference sites included:

- Rosgen stream type,
- valley type,
- drainage area (DA),
- bankfull riffle cross-section area (A_{bkf}),
- bankfull riffle width (W_{bkf}) and mean depth (d_{bkf}) for calculating width-to-depth ratio (WDR),
- width of floodprone area (W_{fpa}) for calculating entrenchment ratio (ER),
- maximum depth at top of bank and bankfull stage for calculating bank height ratio (BHR),
- channel water surface slope (S),
- sinuosity (K),
- median substrate size (d_{50}), and
- estimated Manning roughness coefficient (n).

The subset reference sites collecting pattern and profile data included:

- riffle slopes (S_{rif}),
- riffle lengths (L_{rif}),
- pool spacings (p-p),
- pool lengths (L_{pool}),

[1] Large Woody Debris Assessment https://stream-mechanics.com/wp-content/uploads/2017/12/LWDI-Manual_V1.pdf

[2] NC SQT https://stream-mechanics.com/wp-content/uploads/2017/09/Data-Collection-and-Analysis-Manual_NC-SQT-v3.0.pdf; currently under revision.

- pool maximum depths (d_{mpool}),
- meander lengths ($L_{meander}$),
- belt widths (W_{blt}), and
- radius of curvature of meander bends (R_c).

Field measurement results are presented in the Appendix and in the tables and graphs below. Table 2 summarizes riffle cross-section dimension geomorphic parameters used for Rosgen stream classification. Most of the streams in Ecoregion 66 are B streams with typical entrenchment ratios of about 2. One reference stream is an E stream with a wider valley and entrenchment ratio exceeding 3. Width/depth ratios are highly variable, ranging from 8 to 16.

Table 2. Morphology Dimensions.

Site	Drainage area (mile^2)	Channel slope (ft/ft)	Cross-section area (ft^2)	Bankfull width (ft)	Bankfull mean depth (ft)	Width/ depth ratio	Entrench-ment ratio	Rosgen Stream Class
1	20.8	0.0067	166.8	50.4	3.3	15.2	2.0	B3c
2	2.01	0.0066	36.2	17.7	2.0	8.7	1.8	B4c
3	0.35	0.0555	10.7	11.2	1.0	11.7	2.5	B3a
4	0.11	0.0350	6.0	9.9	0.6	16.2	2.0	B4
5	0.27	0.0171	6.0	8.4	0.7	11.8	1.8	B4c
6	0.56	0.0136	13.4	11.2	1.2	9.3	3.6	E4

Table 3 summarizes estimated bankfull hydraulic parameters (velocity and discharge) for each stream based on gage station data if available and the Manning equation for ungaged streams. The Manning equation, in English units, is:

$$v = \frac{1.486 * \left(R^{2/3}\right) * \left(S^{1/2}\right)}{n}$$

where v is average velocity (feet/second), R is the hydraulic radius (feet), S is average water surface slope (feet/feet), and n is a dimensionless coefficient describing channel roughness, known as Manning's n, which ranges from 0.033 to 0.150 for natural channels. The Cowan (1956) method was used to estimate the Manning's n values based on sediment size, irregularity within a cross-section, variation among cross-sections, obstructions, vegetation, and sinuosity. The bankfull discharge is estimated as the product of average velocity and riffle bankfull cross-section area.

For these six streams, Manning's n values range from 0.047 to 0.060, which match expected values for natural mountain streams. Estimated bankfull average velocities range from 2.6 to 5.1, with variations due primarily to slope and bankfull depth.

Table 3. Estimated Bankfull Hydraulic Parameters.

Site	Drainage area (mile²)	Manning's n	Estimated Bankfull Velocity (ft/s)	Estimated Bankfull Discharge (cfs)
1	20.8	0.052*	4.8	794*
2	2.01	0.047	3.6	130
3	0.35	0.060	5.1	55
4	0.11	0.047	4.0	24
5	0.27	0.054	2.6	16
6	0.56	0.054	3.2	43

* Site 1 bankfull discharge was determined using the USGS gage stage-discharge relationship for the field-measured bankfull stage. Manning's n was calculated from Manning's equation solving for n with known Q.

The graphs in Figures 2 through 5 show relationships of measured riffle bankfull morphological parameters and estimated discharge to watershed drainage area (i.e. regional curves). The six data points representing South Carolina streams are plotted along with reference data from the Ecoregion in North Carolina and Tennessee and the best-fit regression line for those data.

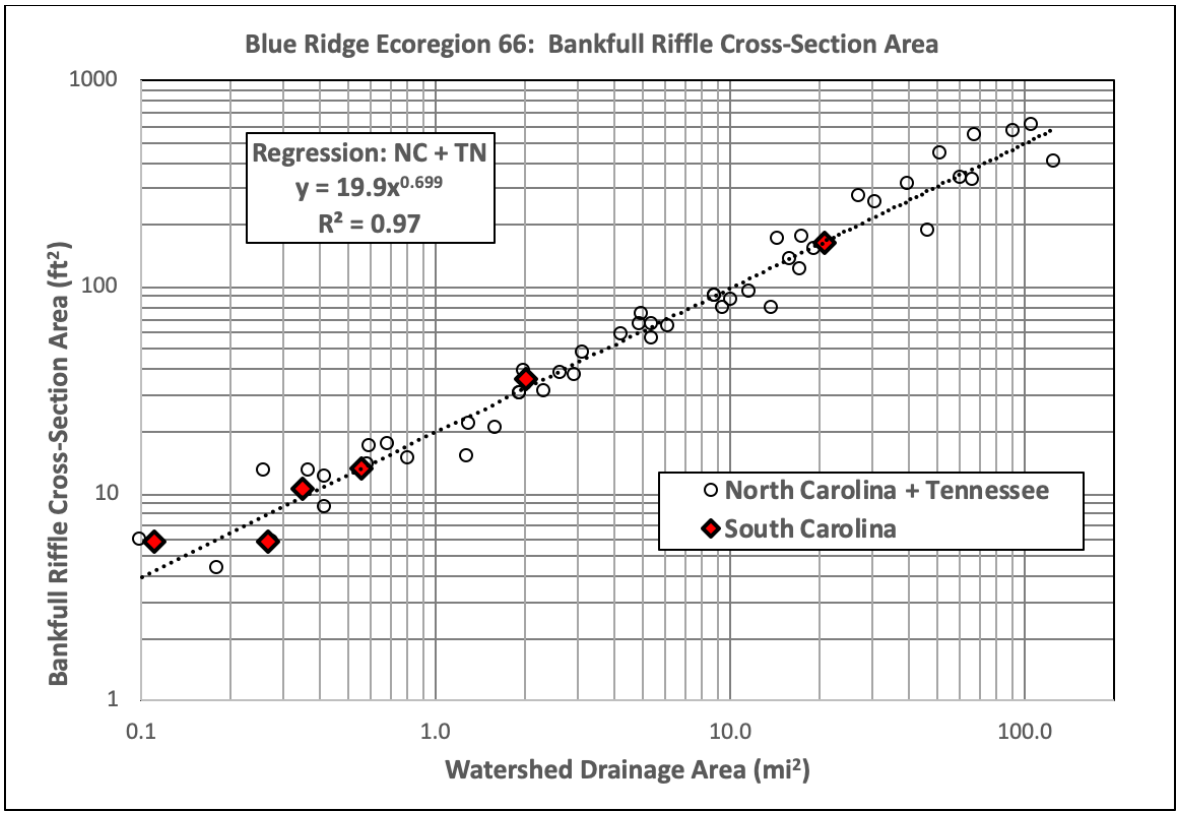

Figure 2. Bankfull riffle cross-section area related to drainage area for Ecoregion 66 streams.

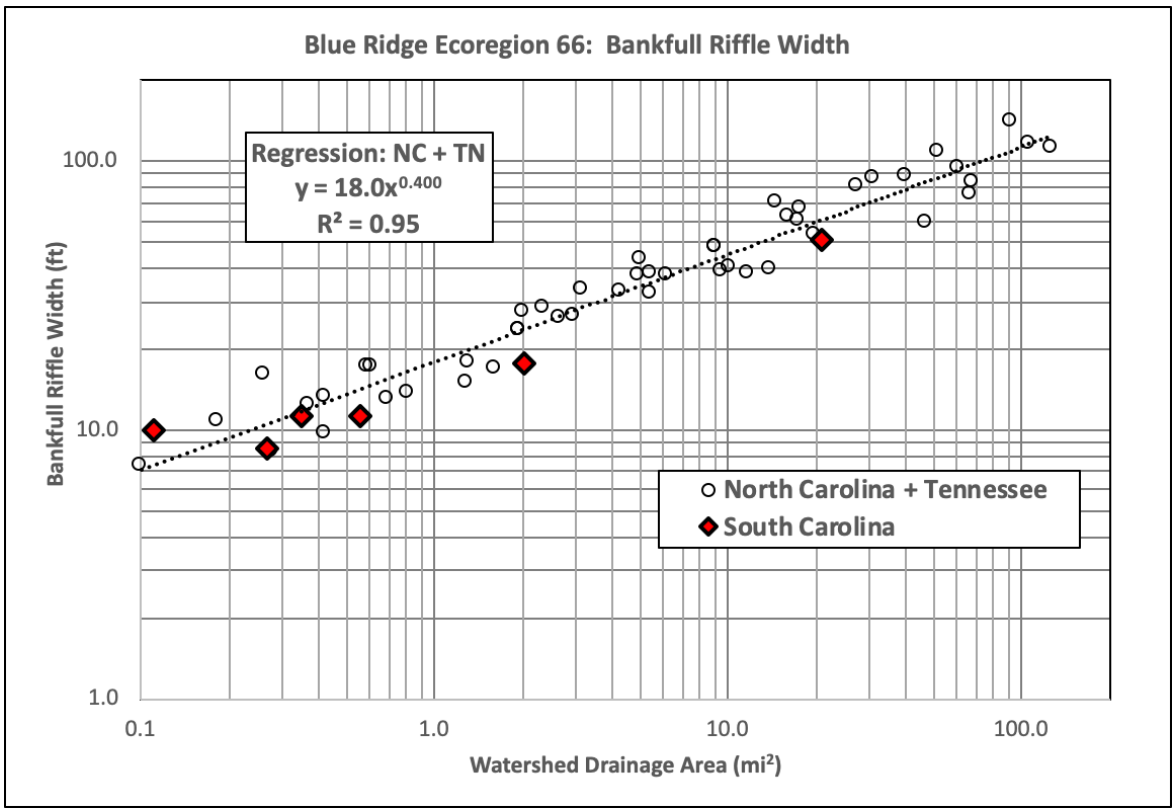

Figure 3. Bankfull riffle cross-section width related to drainage area for Ecoregion 66 streams.

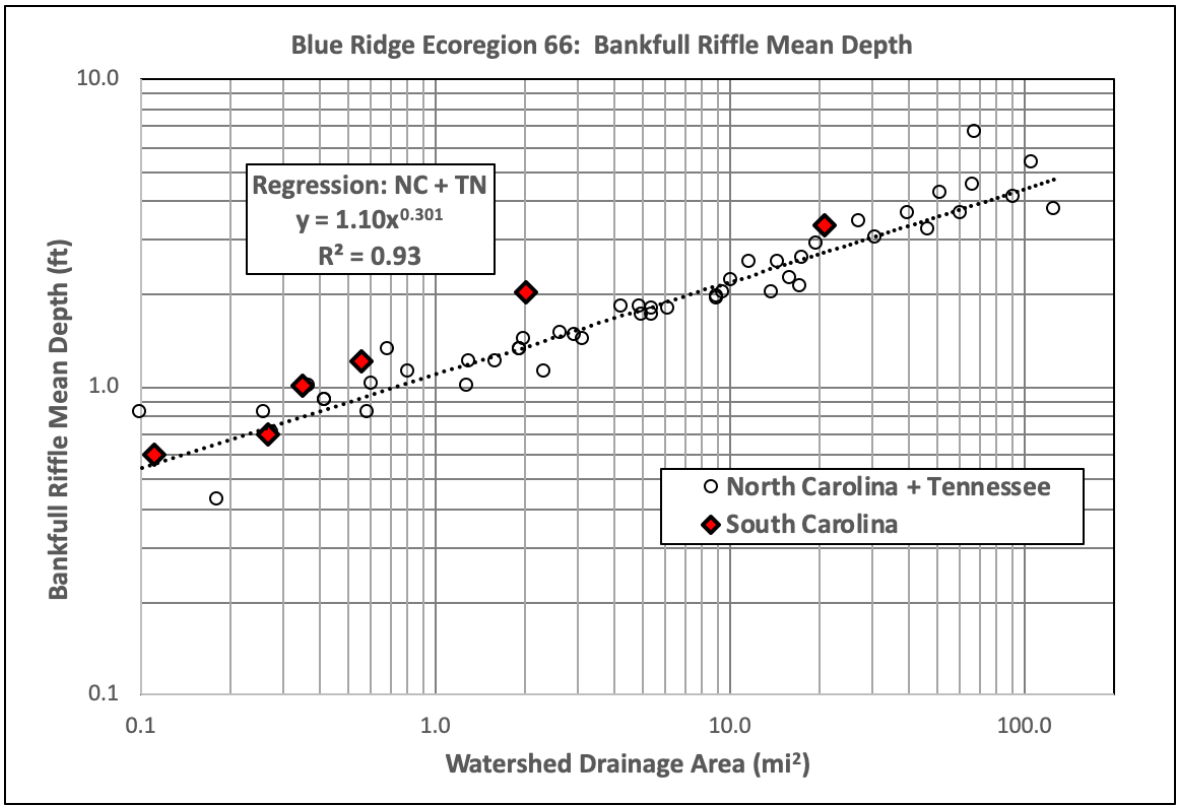

Figure 4. Bankfull riffle mean depth related to drainage area for Ecoregion 66 streams.

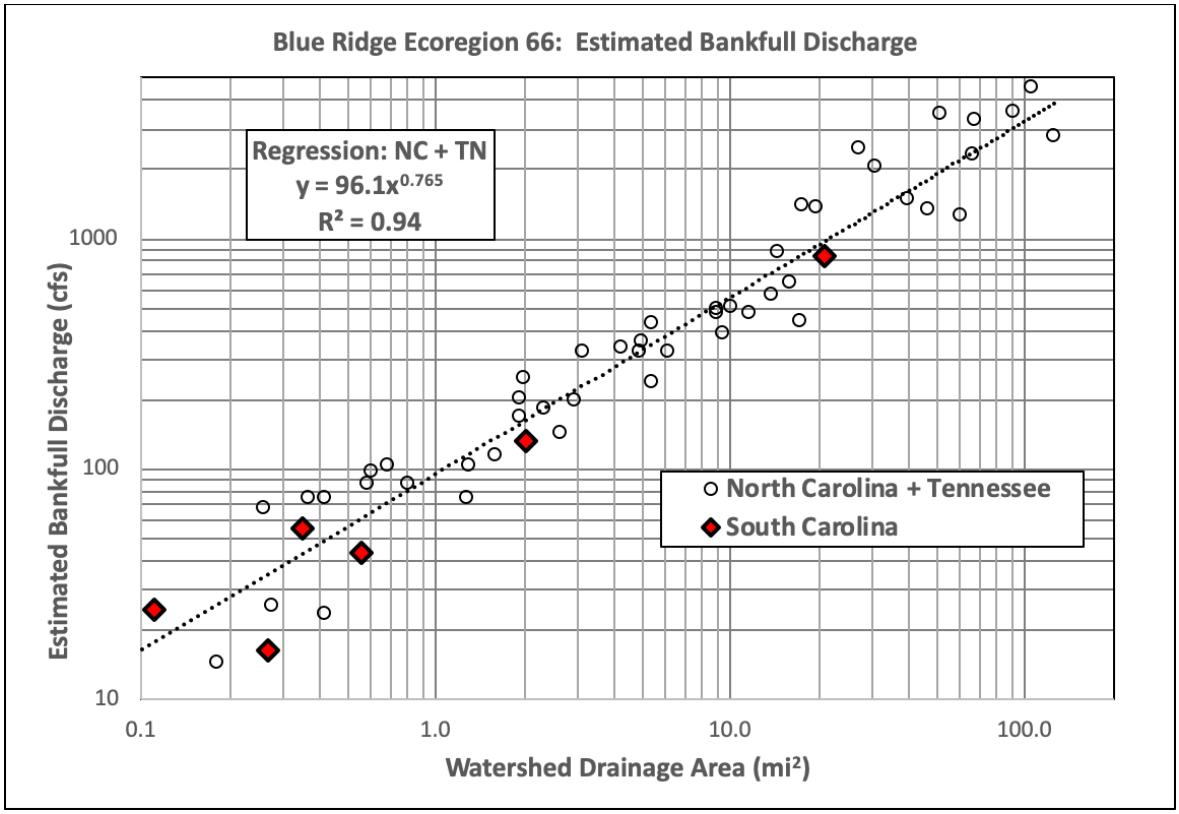

Figure 5. Estimated bankfull discharge related to drainage area for Ecoregion 66 streams.

The South Carolina stream parameters mostly fit within the variability measured in other states in this Ecoregion. Site 5 had a relatively low bankfull cross-section area and estimated discharge for its drainage area, which can be explained by the lower gradient of the measured reach and the undisturbed forest watershed which tends to dampen peak flow response to rainfall. Overall, the South Carolina stream information matches well with North Carolina regional curves.

Table 4 summarizes stream bedform profile data for the five reference streams based on the measured longitudinal profiles presented in the Appendix. For each stream, the median profile parameters and the median dimensionless ratios are listed. All profile parameter ratios are similar to those measured in North Carolina Blue Ridge reference streams. Median riffle and pool length ratios range from 1.7 to 3.3 for riffles and 1.4 to 2.0 for pools. Median pool spacing ratios range from 2.4 to 3.5. Median riffle slope ratios range from 1.0 to 1.7. Median step height ratios for the two reference streams with discernable steps range from 0.06 to 0.10.

Table 5 summarizes stream pattern data for the two meandering reference streams with discernable planform parameters. For each stream, the median pattern parameters and the median dimensionless ratios are listed. All pattern parameter ratios are similar to those measured in North Carolina Blue Ridge reference streams. Median meander length ratios for this small sample size range from 4.7 to 6.3, belt width ratios are 2.6, and radius of curvature ratios are 2.1.

Table 4. Stream Morphology Bedform Profile Parameters.

Site	Drainage area (mile^2)	Median riffle length [ratio to bankfull width] (ft [none])	Median pool length [ratio to bankfull width] (ft [none])	Median pool spacing [ratio to bankfull width] (ft [none])	Median riffle slope [ratio to channel slope] (ft/ft [none])	Median step height [ratio to bankfull width] (ft [none])
2	2.01	55.0 [3.1]	36.0 [2.0]	58.0 [3.3]	0.0114 [1.7]	-
3	0.35	37.0 [3.3]	17.7 [1.6]	35.5 [3.2]	0.0668 [1.2]	1.13 [0.10]
4	0.11	16.5 [1.7]	14.1 [1.4]	24.0 [2.4]	0.0348 [1.0]	0.64 [0.06]
5	0.27	16.0 [1.9]	13.0 [1.5]	20.0 [2.4]	0.0280 [1.6]	-
6	0.56	30.0 [2.7]	20.0 [1.8]	39.0 [3.5]	0.0220 [1.6]	-

Table 5. Stream Morphology Pattern Parameters.

Site	Drainage area (mile^2)	Sinuosity (ft/ft)	Median meander length [ratio to bankfull width] (ft [none])	Median belt width [ratio to bankfull width] (ft [none])	Median radius of curvature [ratio to bankfull width] (ft [none])
5	0.27	1.3	53 [6.3]	22 [2.6]	18 [2.1]
6	0.56	1.3	53 [4.7]	29 [2.6]	24 [2.1]

Table 6 summarizes Large Woody Debris (LWD) assessments for each stream, including the numbers of LWD pieces and dams and the LWD Index scores. The LWDI is 74 at the USGS gage and ranges from 123 to 275 at the five reference streams.

Table 6. Large Woody Debris Assessment Results for Reference Streams, Ecoregion 66.

Site	Number of Pieces	Number of Dams	Piece Score	Dam Score	LWDI
1	4	0	74	0	74
2	7	0	123	0	123
3	10	0	187	0	187
4	14	0	275	0	275
5	7	0	135	0	135
6	6	1	124	18	214